Conference Report

Second Process Specification Language (PSL) Roundtable

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This report describes the Second Process Specification Language (PSL) Roundtable that was held at the University of Maryland, University College on January 13-14, 1999. The Roundtable brought together vendors, end users, and researchers from different manufacturing-related disciplines to discuss matters of common interest relative to the development of the Process Specification Language. The Roundtable was divided into three topic sessions, focusing on 1) the PSL pilot implementations and future directions for the project, 2) the draft Version 1.0 of the PSL specification, and 3) the mapping of the PSL semantic concepts to existing syntactic representations. This paper elaborates on the results of the discussions in the three topic sessions. The main conclusions of the Roundtable were: 1) the content of the proposed Version 1.0 specification (with a few minor additions) provides a good foundation for future work and 2) the identification of a set of application areas and directions to be pursued.

Key words: PSL; KIF; Knowledge Interchange Format; process ontology; process semantics; process specification language, EXPRESS, XML.

Contents

1. Introduction

The goal of the National Institute of Standards and Technology (NIST) Process Specification Language (PSL) project (http://www.nist.gov/psl/) [1] is to create a process specification language that can be common to all manufacturing applications, generic enough to be decoupled from any given application, and robust enough to be able to represent the necessary process information for any given application. Additionally, the PSL should be sufficiently well defined to ensure complete and correct exchange of process information among established applications.

The PSL project, with the help and feedback from colleagues in industry and academia, has come a long way since the first Roundtable in April 1997. Major accomplishments include: 1) determining the information requirements necessary for modeling manufacturing processes [1], 2) analyzing existing process representations to enable the comprehensive development of the Process Specification Language [2], 3) performing the first PSL pilot implementation in which PSL was used as an interlingua to integrate two manufacturing software applications [3], and most recently, 4) developing a draft PSL Version 1.0 specification.

The project reached an exciting and pivotal time in preparing to finalize Version 1.0 of PSL. Because a broad consensus was sought from those who have been involved or have followed the PSL work as well as those who will benefit from standards for process

specification, the PSL project sponsored a second Roundtable on January 13-14, 1999 at the University of Maryland, University College. The attendee mix included 27 participants, representing an even mix of representatives from industry, academia, and government.

The goal of the Roundtable was to discuss and come to consensus on the following three topics:

1) Recap lessons learned from the first PSL pilot implementation and set the direction for future pilot implementations.
2) Identify and review issues involved with mapping the PSL semantic concepts to existing textual representations (specifically, research performed mapping to EXPRESS [4] and the eXtensible Markup Language (XML) [5]).
3) Discuss the draft PSL Version 1.0 specification and come to consensus on the contents of the specification.

Based on the consensus that was achieved at the Roundtable and building on results of the preceding phases of this project, the PSL project will shortly finalize the Version 1.0 specification of the Process Specification Language and lay the groundwork for future pilot implementations to help continuously expand and improve the PSL specification.

2. Roundtable Overview and Format

The organization of the Roundtable was unique. There were actually two distinct portions of the event, the virtual and the physical portion of the Roundtable, where the virtual por-

tion fed directly into the physical portion.

2.1. Virtual Roundtable

The Roundtable began on December 14th with an email discussion among the participants. The purpose of this email discussion was two-fold:

- To allow participants to introduce themselves to the other participants. By doing this electronically, it allowed participants to jump directly into the technical issues at the beginning of the physical Roundtable.
- To allow participants to introduce issues they would like to see discussed at the physical Roundtable. This discussion allowed the PSL team to create an agenda that was directly in line with the participants' interests while addressing the goal of discussing and coming to consensus on Version 1.0 of PSL and setting the direction for future pilot implementations.

Issues discussed during the virtual Roundtable included:

- What other manufacturing-related fields have a strong need for a process specification language that the project should focus on in the future?
- Have other groups attempted to develop mappings from well-defined semantic concepts to existing representations and how can those efforts be leveraged?
- What types of representation would be best to provide mappings to?

- What else can the PSL project do to make it easier for vendors to get involved?
- Specific challenges involved with the mapping of the PSL semantic concepts to EXPRESS.

In addition, papers and emails were sent out to allow colleagues who have not been closely involved in the project to get up-to-date quickly.

2.2. Physical Roundtable

The physical Roundtable began with an overview by Craig Schlenoff (NIST), who discussed the goals of the Roundtable, described the Roundtable format, and gave a summary of the history and current status of the NIST PSL project. The rest of the day focused on a discussion of two topics, each of which was summarized, discussed, and followed by a written submission of participants' conclusions.

The first topic, "Lessons Learned from the First PSL Pilot Implementation and Direction Setting for Future Pilots," was facilitated by Craig Schlenoff. A summary and the results of the first PSL pilot implementation were presented and discussed [3]. In this pilot implementation, PSL was used as a neutral representation to exchange process information between the IDEF3-based ProCAP process modeling tool[1] and the C++-based ILOG Scheduler. This presentation was followed by presentations from Florence Tissot

(KBSI) and Mihai Ciocoiu (University of Maryland). Both presentations focused on translation issues, with Tissot presenting a methodology for translator writing and Ciocoiu focusing on the practical issues pertaining to translation. These presentations gave enough background of ongoing work to allow participants to discuss and answer the following questions:

- What other manufacturing-related areas have a strong need for a process specification language that the project should focus on in the future?
- What else can the PSL project do to make it easier for vendors/users to get involved?
- What are the translation issues involved in using a formal ontology as an interchange language?

The second topic, "A Review of the Draft PSL Version 1.0 Specification," was facilitated by Michael Gruninger (University of Toronto). The goal of this topic was to discuss and come to consensus on the contents of the draft Version 1.0 specification. The session started with a presentation describing the current status of the specification. It also explained the decisions that were made along with the rationale. This presentation led to the discussion of the following questions:

- Are the concepts introduced in the draft Version 1.0 specification an appropriate foundation to model manufacturing process information?
- Are the definitions of those concepts in line with users' intuitions?

[1] Certain commercial equipment, instruments, or materials are identified in this paper to foster understanding. Such identification does not imply recommendation or endorsement by the National Institute of Standards and Technology, nor does it imply that the materials or equipment identified are necessarily the best available for the purpose.

- Are the concepts presented and organized in a way that would make it easy for a user to understand?

At the end of the first day, a brief discussion ensued focusing on the ontology management challenges that were brought to light in previous discussions. Topics discussed included:

- Issues with respect to version control of extensions.
- A policy for submission and review of proposed extensions.
- What should be contained in a header file for PSL extensions?
- Tools and/or techniques that would make it easier for a user to view/navigate through the PSL concepts.

On the second day, the third topic "Issues Involved With Mapping the PSL Semantic Concepts to Existing Representations" was facilitated by John Valois (STEPTools, Inc.) The session started with a very brief overview by Schlenoff describing the purpose of the exercise of mapping PSL to existing representations. Briefly stated, the underlying representation of PSL (the Knowledge Interchange Format (KIF) [6]), although very appropriate for this work, is not very human-readable. For this reason, efforts are underway to map the concepts represented in KIF into existing representations that are easier for a human to read and understand. This session continued with presentations from John Valois and Josh Lubell (NIST) describing their work in mapping the PSL concepts to EXPRESS [4] and the eXtensible Markup Language (XML) [5], respectively. These presentations primed the audience to address the following questions:

- What other representations, aside from EXPRESS and XML, would be useful to provide mappings to?
- What is the best mechanism for providing these mappings?

At the conclusion of this topic, decisions were made on how to proceed and the Roundtable concluded.

3. Roundtable Details and Results

The Roundtable was broken up into three sessions, each focusing on specific technical issues facing the PSL development. These issues include: 1) translation issues and future direction for the project, 2) content and structure issues relating to the release of PSL Version 1.0, and 3) issues pertaining to the mapping of semantic concepts to existing presentations. In addition, a separate, short session was held at the end of the first day to discuss management issues pertaining to the growth of the PSL ontology.

3.1. Topic 1: Lessons Learned from the First Pilot Implementation and Direction Setting

This topic started out with a description of how PSL was used to integrate the IDEF3-based ProCAP process modeling tool and the C++-based ILOG Scheduler [3]. In this pilot implementation, the process-related concepts from each of these applications were identified, formally defined and captured within the PSL Ontology. Then, two translators were written that 1) translated the concepts in ProCAP into the existing and newly defined

concepts in PSL, and 2) translated the concepts in PSL into the ILOG representation. For this pilot implementation, a scenario developed by Ken McKay, as part of his work with Consortium for Advanced Manufacturing – International (CAM-I), was used [7]. This scenario, nicknamed the "Factory From Hell," describes the goals, constraints, and issues faced by a fictitious motor works factory in developing model cars. The content of the scenario was inspired from insights gained from visits to real factories.

Following this, work was presented describing methodologies and practical considerations when using PSL for translation. These presentations not only described on-going work but also raised some issues that NIST is currently trying to address. A description of these issues and the pertinent discussion can be found in Sec. 3.1.3.

3.1.1. Scope and Purpose of PSL

Before one can start talking about detailed issues with respect to translation and deciding on future directions, it is important to clarify what the scope and purpose of PSL will be. Although all agreed that the ultimate goal of PSL was for information exchange, there were a number of different opinions regarding other ways in which it could be used. These included:

- As a generic process representation language.
- As a "capability reference for methods" that would allow a target application to inherit PSL's formal mechanics.

- The high level concepts of PSL could be used to model process in multiple domains and even integrate multiple domains at the highest level of process.

In general, it was decided that PSL could be used for any of these purposes as long as it did not compromise its ability to serve as an exchange representation.

With respect to scope, there was a large amount of concern from the participants that the PSL project has not yet set bounds on what will be included and what will not be included. Various participants disagreed on whether certain types of information should be included in the language. These were:

- When (the actual time and date) an activity should begin
- Concepts related to decision support
- "How" the process will occur

In general, it was decided that PSL is meant to represent enough information about a process so that it could be used however necessary. It is not the goal of PSL to dictate exactly when or how a process happens, this is up to the decision structure of the individual company. PSL must only be able to represent enough information about the process to allow this type of activity to take place.

Another issue that arose is how “deep” PSL should go with respect to modeling process information. Is it the job of PSL to model the details of process specification for any

specific domain? For example, should PSL model the details of the activities that take place in a specific manufacturing operation (e.g., should a concept exist that defines drilling, sanding, etc.) or is this at a level of detail that is too deep for the scope of PSL. It was generally decided that the PSL standard would most likely not include concepts for these types of operations. General activity concepts presented in the PSL standard could be easily extended by the user in specialized extensions to capture these concepts. However, if done properly, these extensions could find their way into the standard in the future.

3.1.2. Proprietary Issues

Another concern communicated dealt with the proprietary nature of process information. In general, the way that a company performs a process is what gives it an advantage over other competing companies. Therefore, companies are very reluctant to make available these proprietary secrets.

However, with the growth of "virtual enterprises," companies are working more closely together and sharing information. Process information will be one of the many types of information being shared. How can a company share necessary information without giving away their proprietary advantage?

One way that PSL could help with this is to be able to represent information at different levels of abstraction. In this way, only information that is necessary could be represented

and it could be generalized in a way that would still convey the necessary information without going into a level of detail that would infringe on a company's advantage. It was therefore suggested that PSL be developed with this type of architecture in mind.

3.1.3. Translation and Human Interaction Issues

It was suggested that in order to get PSL accepted by industry, PSL must minimize the work a company would need to perform to be "PSL compliant." This would involve making the language easy to read and understand and allowing for quick and seamless translator development.

The overwhelming consensus was that an extensive set of documentation, tutorials, figures, and numerous examples would be extremely beneficial. One participant emphasized that "the documentation should be written such that "non-geeks" can understand and implement PSL." Other participants suggested that software would be useful to shield a user from having to interact directly with the logic side of PSL. Most felt that although the formal logic side of PSL was essential for this work, it was not something with which a user should directly interact.

3.1.4. Approach and Future Direction

This discussion focused on evaluating the approach the PSL project has been taking and on determining in what direction the project should proceed. In general, most participants felt that the project's approach had an appropriate mix of theoretical and pragmatic considerations. However, with the upcoming release of the finalized PSL Version 1.0 Specification, there were strong concerns that the project would need to focus more heavily on the practical issues pertaining to using PSL as an exchange specification. One participant suggested that directions pursued by STandard for the Exchange of Product model data (STEP), officially ISO 10303 [8], might be appropriate for this project. This suggestion is being explored.

In general, there seemed to be two suggested directions in which the project could proceed. The first dealt with expanding the current ontology to incorporate concepts in manufacturing-related fields that have not yet been explored. Specific suggested fields included:

- Concurrent Engineering
- Supply Chain Management
- Manufacturing Resource Planning
- Business Processes
- Virtual Enterprise Composition Process
- Activity Based Costing

- Generating Bids
- Agent-Based Systems
- Design for Manufacturing

The second direction focused more on ensuring that the current concepts within PSL are sufficient to completely capture the manufacturing fields that have been explored. In other words, when PSL was extended to capture scheduling information, only a single scheduling tool was studied. Perhaps the PSL members should go back and explore other scheduling tools to ensure more scheduling-related concepts are captured. One participant captured this well when he said “PSL should explore the portability and determinism of the process specification (e.g., making sure what is there is ‘correct’).”

3.2. Topic 2: Discussion of Draft Version 1.0

The goal of the second topic was to present and discuss the draft PSL Version 1.0 specification with the hope of coming to consensus on the content of the release. The discussion focused on two main topics: the content of PSL and the relationship of PSL to other models. Both topics are discussed below.

3.2.1. Content of PSL

For the most part, the participants were very satisfied that the content of the proposed PSL Version 1.0 is appropriate for the release. However, discussion did ensue focusing

mostly on the types of information that participants expected to see in the PSL specification that were not apparent. These included (in no particular order):

- Information which is contextual (e.g., external) not for translation but as "information fields" for validation and other introspective tasks
- The representation of uncertainty (e.g., this process has a probable duration and a possible range)
- Pointers to other models which contain information that is related to process specification (e.g., STEP's Part 49 (Process Structure and Properties) and Application Protocol 213 (Numerical Control Process Plans for Machined Parts)
- Conditions (start and end)
- Representation of inverse causality (e.g., given a set of processes, what type of product can be made)
- Representation of inputs and outputs
- Further classification of activity, with appropriate definitions, to model transformation, assembly, and disassembly activities
- Activity dependencies via data
- Procedural information (e.g., rules)
- State and control
- The relationship between plans and part numbers
- Assembly process
- Spatial information

Some of the concepts listed above are already being researched to be included in PSL, some have not, although many will most likely find their way into PSL during later releases. This discussion will prompt the PSL team to look over the PSL specification and determine which of these concepts should be included in the Version 1.0 of PSL. In addition, it strengthened the point mentioned earlier that the document for PSL needs to be very clear and easy to read such that a user can easily determine if the concept they are looking for is currently captured in PSL.

3.2.2. Relationship to Other Models

It was widely accepted that the goal of PSL is not to model process-related information that already appears in other information models. Instead, there should be a link from PSL to other supporting representations, when and where appropriate. There could be a number of different representations related to PSL, including:

- A product representation model
- A process characterization model
- A resource description model
- A business practices model

One of the main discussions in this session dealt with how to best integrate PSL and STEP. For example, when one is trying to describe assembly information, how much does

one describe in PSL and how much does one leave up to STEP? STEP already has concepts such as “next-higher-assemblies,” so there is no need to model that type of concept in PSL.

Another issue is the method in which the information would be linked. For example, one could link STEP and PSL via standardized methods: EXPRESS, Part 21 (the textual exchange mechanism), or the Standard Data Access Interface (SDAI), or one could link the information via other standards (various parts of STEP which deal with process information). It was suggested that one mechanism for determining the best approach is to look at the enterprise modeling efforts ongoing in numerous standards’ bodies and leverage their work.

Lastly, there was some discussion as to where PSL stops and where a process characterization model begins. A process characterization model would describe the details of an activity independent of a specific application. For example, PSL would simply reference an activity and describe some of its high level characteristics while a characterization model would describe more detailed aspects such as the dynamics/kinematics of that activity, tool chatter, etc. There was little doubt that these two models would work together, the concern was where to draw the boundaries. Although these boundaries are still fuzzy, there seemed to be a lot of interest among the participants for NIST to explore the creation of a process characterization model (as a separate project).

3.3. Topic 3: Mapping of the PSL Semantic Concepts to Existing Representations

The goal of the third topic was to make the participants aware of the work that was going on within the PSL project in mapping the PSL semantic concepts to the XML and EXPRESS representation with the hope of resolving issues that arose during this mapping. In addition, a sub-goal of this topic was to identify other representations that may be appropriate to map to. Briefly stated, the underlying representation of PSL (i.e., KIF), although very appropriate for this work, is not very human-readable. For this reason, efforts are underway to map the concepts represented in KIF into existing representations that are easier for a human to read and understand. The discussion seemed to fall neatly into two separate topic areas: the role of presentations and specific issues with respect to the mapping to EXPRESS. The discussions of these topics are described below.

3.3.1. Roles of Presentations

Although originally grouped together, the participants identified two distinct, yet equally important, types of presentations. They are:

1. A presentation that is logically equivalent and equally as expressive as KIF but easier to look at and understand (e.g., conceptual graphs).
2. A presentation that is prototypical to a whole range of applications (e.g., EXPRESS, XML).

The first type of presentation would fulfill the original requirement that was stated for a presentation; namely, that it would represent all of the concepts represented in the PSL Ontology yet provide a more user-friendly way for users to read and understand the contents of the language. This presentation would be sound and complete with respect to the PSL Ontology. It would also provide a read/write capability that would allow a user to only interact with an easy-to-read, graphical interface while still having the capability to edit the contents of the ontology.

The second type of presentation would provide a completely different set of purposes. These purposes include:

- providing a link to other user communities that are interested in PSL and are already accustomed to interacting with a different type of presentation (e.g., EXPRESS for the STEP community)
- allowing PSL to utilize an established set of tools and techniques that are already available in other communities but rely on a different syntactic representation (e.g., EXPRESS tools developed by various vendors)
- providing a mapping to commonly used representations to facilitate the act of translator writing for tools that use these representations (e.g., by creating a mapping to XML, all tools that use XML as their underlying representation will easily be able to write translators to PSL by basing it on the mapping).

This type of presentation will be sound but not necessarily complete with respect to the PSL ontology and will be used primarily for read-only purposes (e.g., to view the contents of the ontology).

Although originally grouped together, both of these types of presentations are going to be pursued in the PSL project.

3.3.2. Specific Issues Pertaining to Mapping to EXPRESS

The presentation describing the mapping of the PSL semantic concepts to EXPRESS seemed to generate a fair amount of concerns. In this presentation, a description of the methodology used to map each concept in the PSL Ontology to a construct in EXPRESS was described. In addition, a description of how this mapping would involve the use of EXPRESS-X [9] and EXPRESS was presented. Some of the comments voiced by the participants included:

- All concepts (and their extensions) introduced in PSL should be directly modeled in EXPRESS, not represented as strings.
- The EXPRESS model should be as close as possible to the KIF model in structure. Also, the terminology in the EXPRESS model should only be that used in KIF.
- Should the project use experimental information technology (EXPRESS-X, EXPRESS-2) for mapping to presentations?

These considerations, among others will be taken into account during the second pass of the mapping effort.

3.4. Additional Topic: Management of the PSL Ontology

Although not originally scheduled as a topic for this Roundtable, the participants seemed to voice a fair amount of concerns about how the growth of PSL would be handled in the future. Management of the PSL Ontology was identified as one of the most important aspects of the project to ensure PSL's success. Briefly stated, PSL already contains over 300 concepts, about 30 extensions and has multiple people involved in developing new extensions. Considering the rate at which PSL is expected to grow, there needs to be mechanisms in place to facilitate this growth. For example, it was identified that the following should be explored:

- Mechanisms for version control of extensions in the Ontology.
- Mechanisms for a review process to ensure that newly proposed extensions are consistent with the current extensions and appropriate.

In addition, there were numerous opinions pertaining to how PSL should grow. For example, some participants thought that the growth of the extensions should focus on domains (e.g., assembly, material removal, etc.) while others thought PSL should focus on various applications in the life-cycle (e.g., planning, scheduling, simulation). Currently, the

PSL project is taking a more life-cycle approach although it is keeping an eye on how this would feed into a domain-specific approach.

4. Conclusions and Future Directions

The goal of the PSL Roundtable was to assemble experts in the process representation community to come to consensus on the content of the current state of the PSL and to determine the project's future direction. These goals were in fact achieved with the overall consensus on the contents of the proposed Version 1.0 specification (with a few minor additions) and with the identification of a set of application areas and directions that the project should pursue.

One of the most striking aspects of the Roundtable was the diversity of background of the people that attended. Almost all participants had a slightly different interpretation of how the PSL could be used and tailored to suit their needs. These interpretations ranged in usage from an exchange specification, to an underlying representation, to a "capability reference for methods" that would allow a target application to inherit PSL's formal mechanics. Pertaining to domains of usage, PSL was suggested for use in business, control, simulation, assembly, and healthcare applications.

Many of the participants in the Roundtable discussion showed great interest in seeing this project continue and are even tailoring their work to incorporate the use of PSL as it matures.

This next few months will be a very exciting time for the PSL project, building off of the results of the discussion at the Roundtable. Within this time, the PSL effort will be releasing Version 1.0 of the PSL specification, re-assessing the contents of the language to ensure its complete coverage of manufacturing domains that have already been addressed, performing another pilot implementation to continually expand the robustness and usefulness of the language, and proposing PSL as an international standard.

5. Appendix A: Roundtable Agenda

13 JAN: 8:30 - 5:00

8:30 - 9:00 Registration

9:00 - 10:00 Introductory Remarks: Goals of the Roundtable, the Roundtable Approach, and Project Overview and Status

BREAK

10:30 - 12:30 Presentation/Discussion/Written summaries of Topic 1

12:30 - 1:30 LUNCH

1:30 - 3:30 Presentation/Discussion/Written summaries of Topic 2

BREAK

4:00 - 5:00 Wrap up of Day 1: Discussion of identified issues, topics

5:00 - 6:00 Demo and Appetizers, Room 2112

14 JAN: 9:00 - 1:30

9:00 - 11:30 Presentation/Discussion/Written Summaries of Topic 3

11:30 - 12:30 Identify and discuss remaining issues

12:30 - 1:30 LUNCH / ADJOURN

TOPICS:

TOPIC 1: LESSONS LEARNED FROM THE FIRST PSL PILOT IMPLEMENTATION AS WELL AS SETTING THE DIRECTION FOR FUTURE PILOT IMPLEMENTATIONS. (Facilitator: Craig Schlenoff, NIST)

TOPIC 2: DISCUSSION OF THE DRAFT PSL VERSION 1.0 SPECIFICATION WITH THE HOPE OF COMING TO CONSENSUS ON THE CONTENTS OF THE SPECIFICATION. (Facilitator: Michael Gruninger, Univ. of Toronto)

TOPIC 3: ISSUES INVOLVED WITH MAPPING THE PSL SEMANTIC CONCEPTS TO EXISTING TEXTUAL REPRESENTATIONS (SPECIFICALLY, EXPRESS AND XML), (Facilitator: John Valois, STEPTools, Inc.)

6. Appendix B: Participants

Participant	**Affiliation**
Mihai Ciocoiu	University of Maryland, College Park
Shaw Feng	NIST
Jim Fowler	NIST
Ted Goranson	Sirius-Beta
Michael Gruninger	University of Toronto
Satyandra Gupta	University of Maryland, College Park
Jeffrey Herrmann	University of Maryland, College Park
Nenad Ivezic	Oak Ridge National Laboratory
Anne Jones	Wizdom Systems
Thomas Kramer	NIST
Edward Lin	University of Maryland, College Park
Josh Lubell	NIST
John Michaloski	NIST
Richard Morris	NIST
Hector Munoz-Avila	University of Maryland, College Park
Dana Nau	University of Maryland, College Park
Ajit Pardasani	Integrated Manufacturing Technologies
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Naresh Raja	Deneb Robotics, Inc.
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Craig Schlenoff	NIST
Debra Stephens	Raytheon Systems
Florence Tissot	Knowledge Based Systems Inc.
Richard Wysk	Pennsylvania State University
John Valois	STEP Tools, Inc.

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Schlenoff received his Masters degree from Rensselaer Polytechnic Institute (RPI) and his Bachelors degree from the University of Maryland, College Park, both in mechanical engineering.